Meeting the Renewable Energy Challenge:

What Will it Take to Reach Solar PV's Ultimate Potential

May 8, 2006

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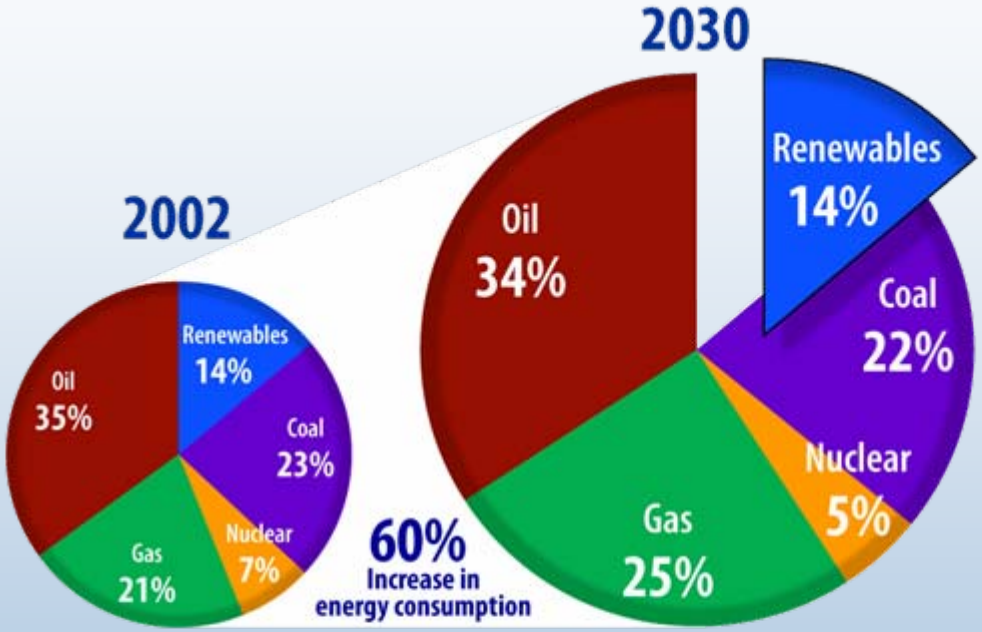
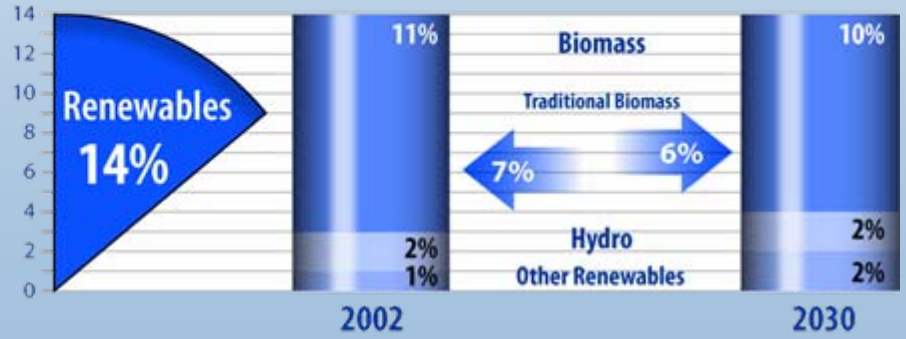
Presented at the 2006 IEEE 4th World Conference on Photovoltaic Energy Conversion in Waikoloa, Hawaii

NREL/PR-100-40011

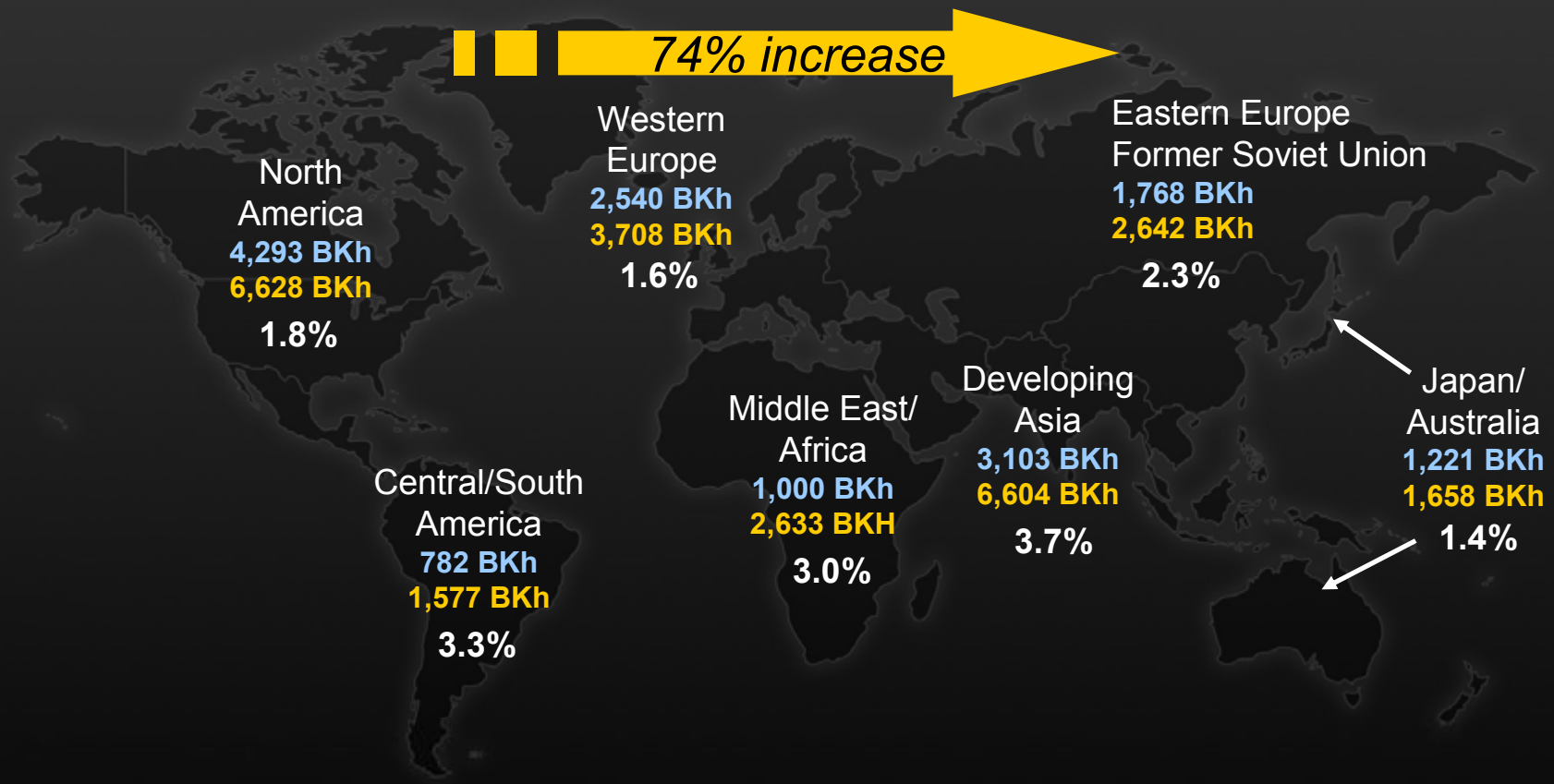
World Energy Supply and the Role of Renewable Energy



Source: OECD/IEA, 2004



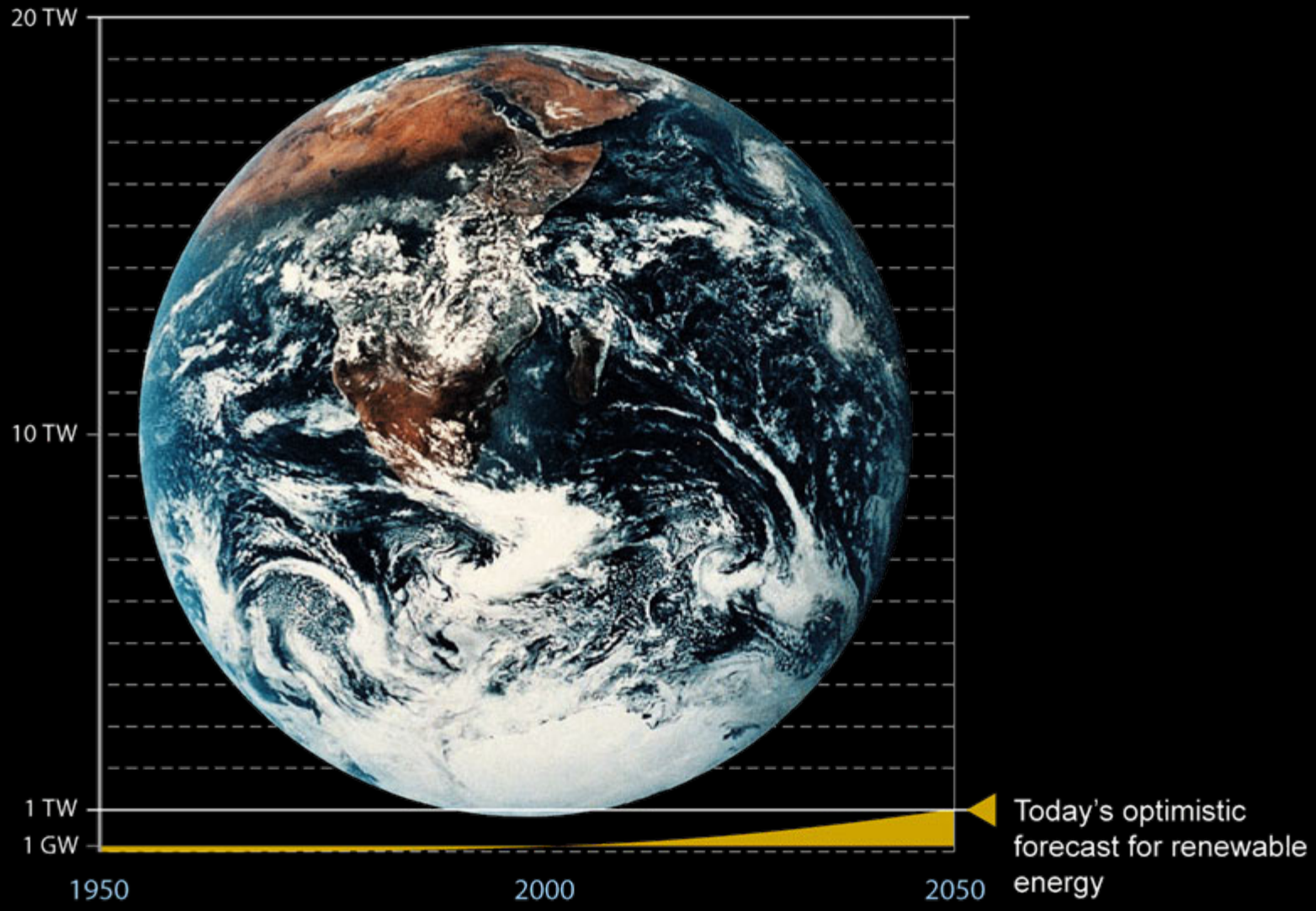
Electricity Outlook: 2001-2025



- Total annual average world electricity growth - 2.4% from 2001 to 2025
- Growth rates in transitioning economies higher than developed economies
- Natural gas and coal will be near-term fuels of choice for generation
- Distributed generation and renewable energy will offer attractive options

Source: International Energy Outlook 2003, Table A9

Magnitude of Challenge Requires Global Action and a Change in Trajectory



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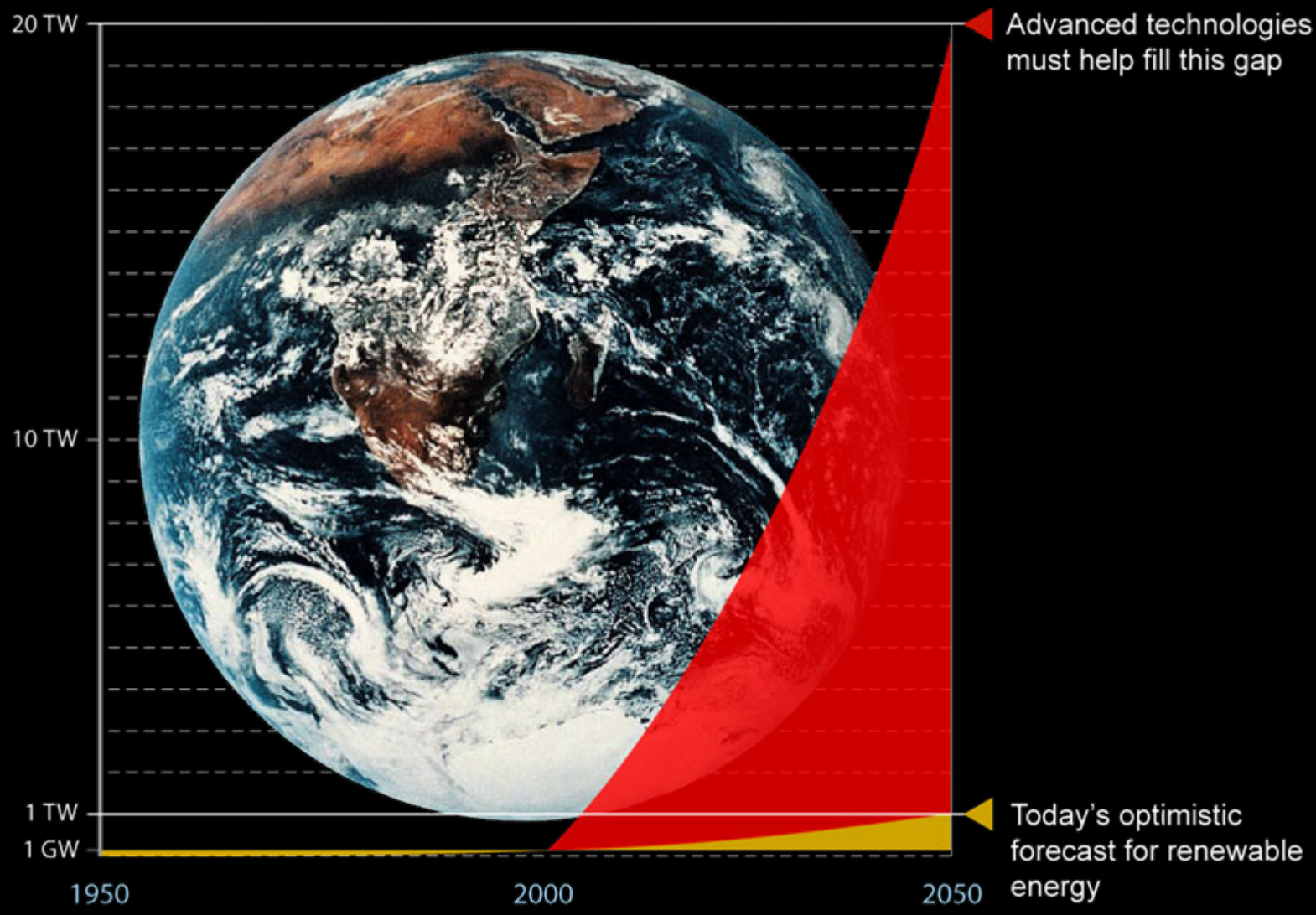
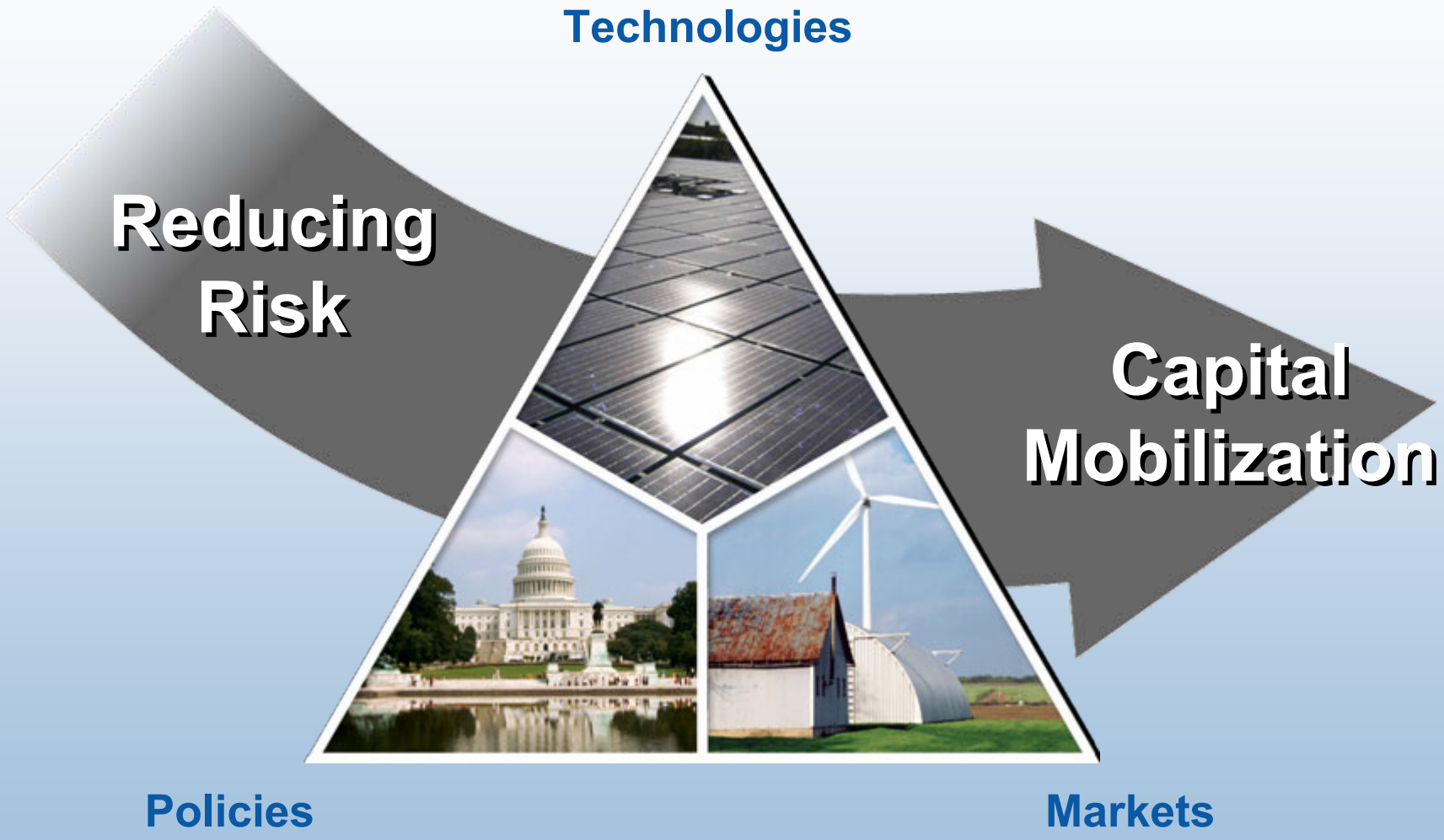
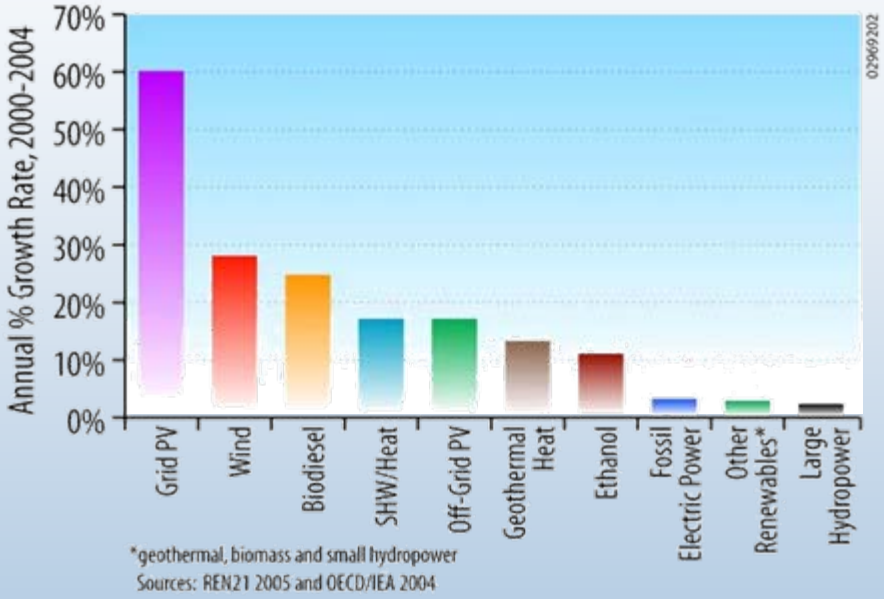


Getting There Involves…

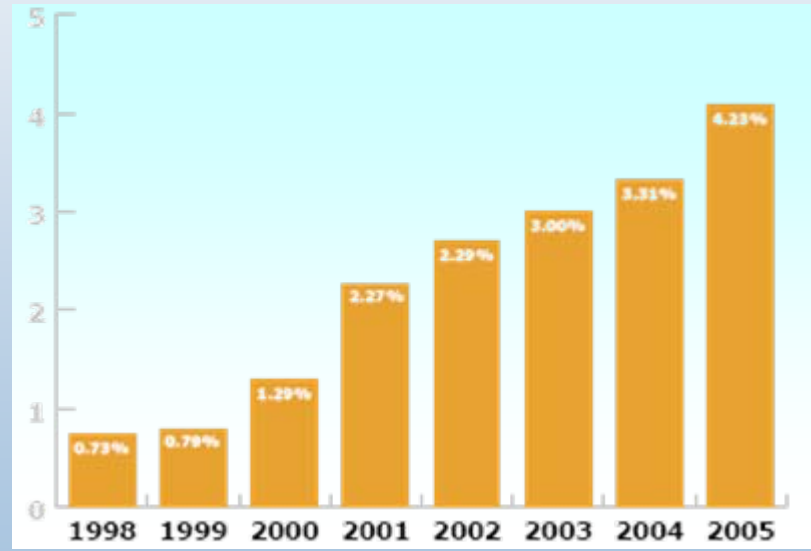


Renewable Energy is Growing

Renewable Energy Annual Growth Rates



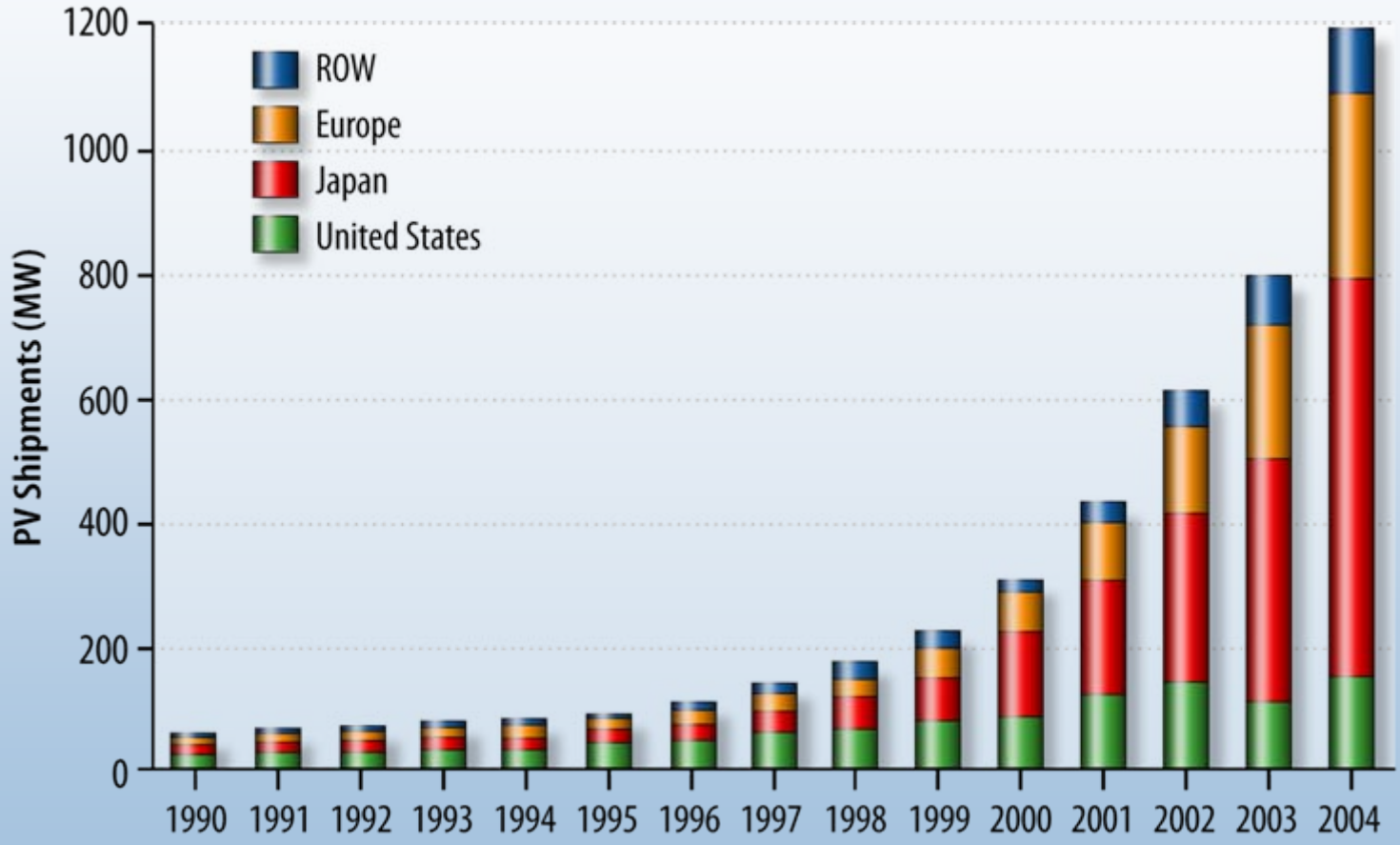
Energy-Tech Investments as a Percent of Total U.S. Venture Capital



Source: Nth Power LLC

PV is a $10B+ industry and a $1B venture capital market

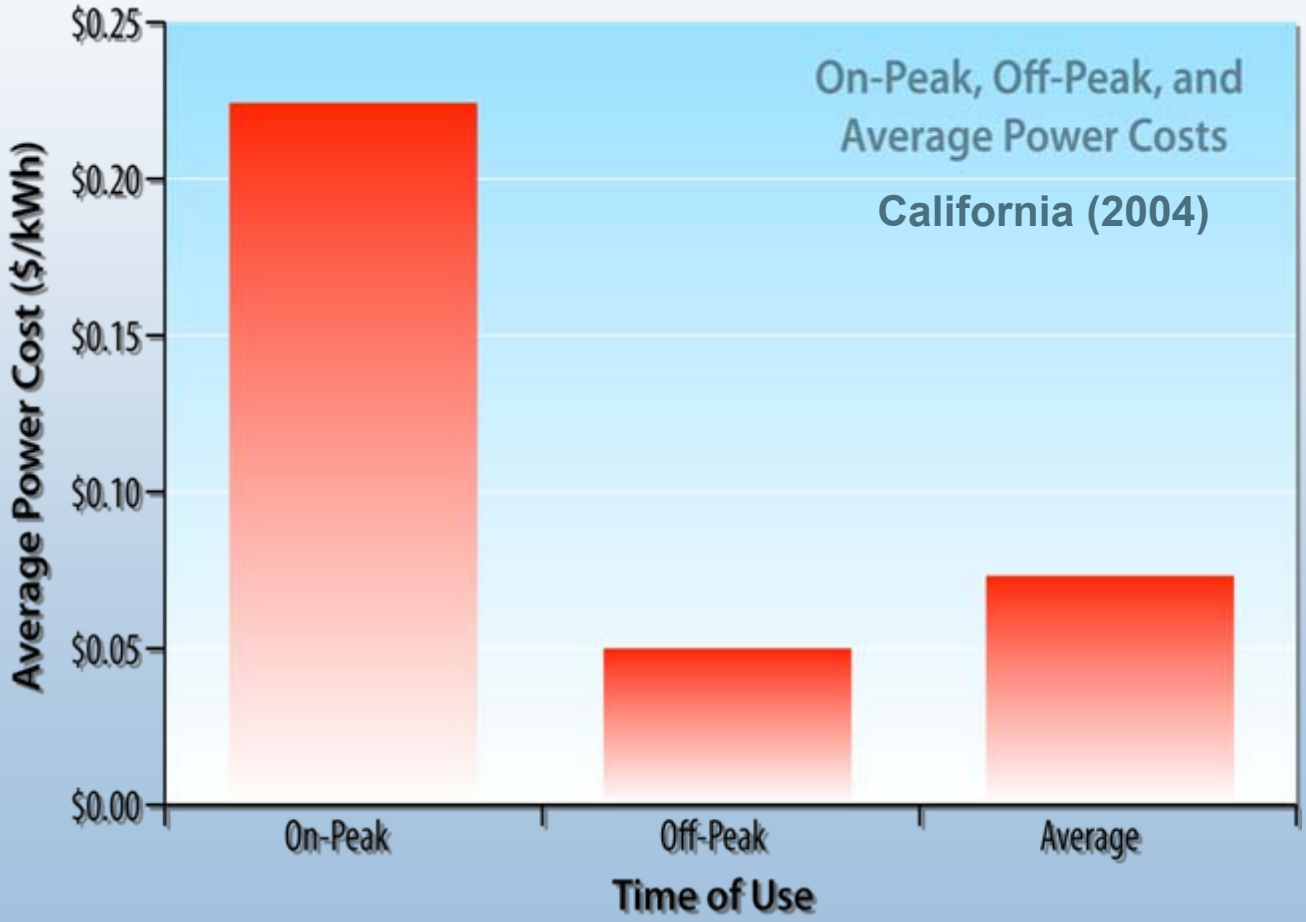
Worldwide PV Shipments



Source: Paul Maycock, PV News, February/March 2005.

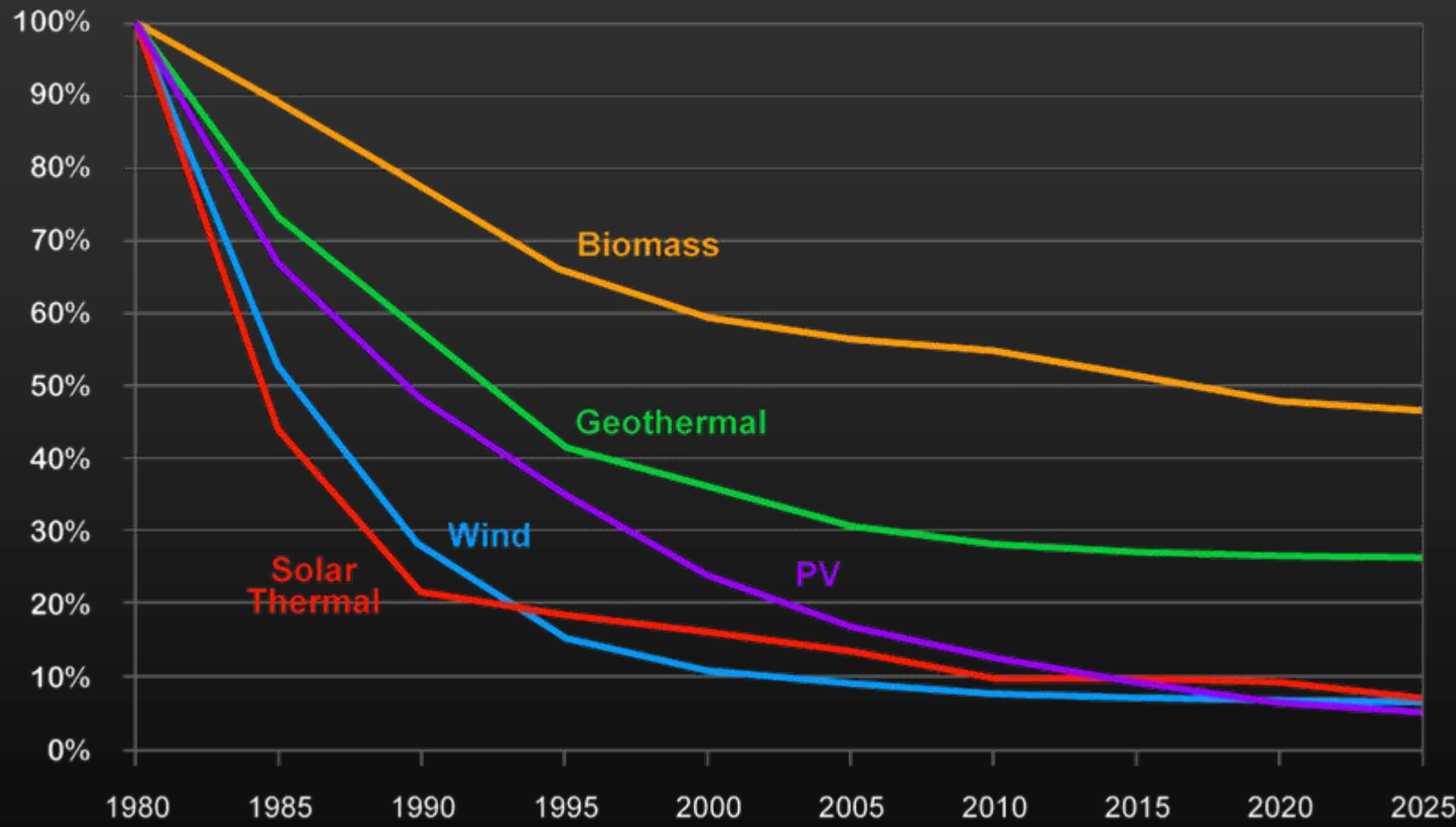
Distributed generation *is* the immediate market

. . . *peak power*



Renewable Energy Electricity Generation Costs as Percentage of 1980 Levels:

Historical and Projected

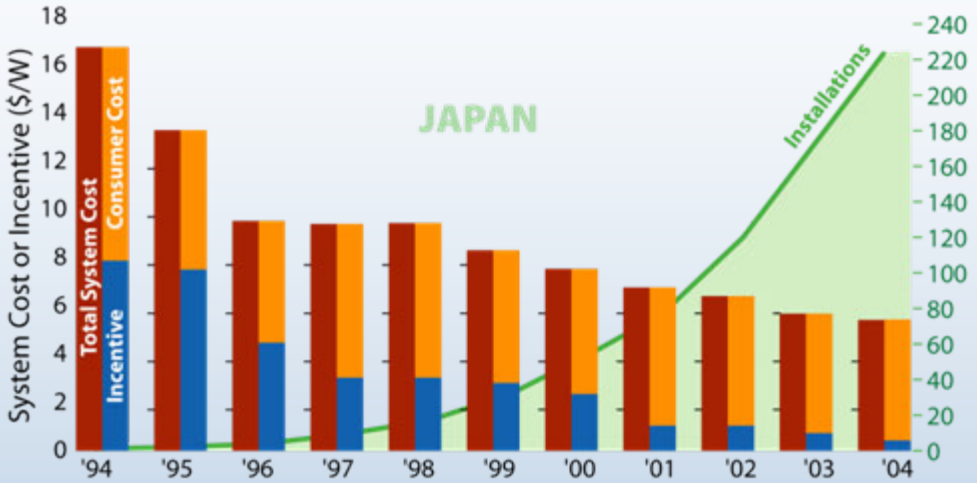


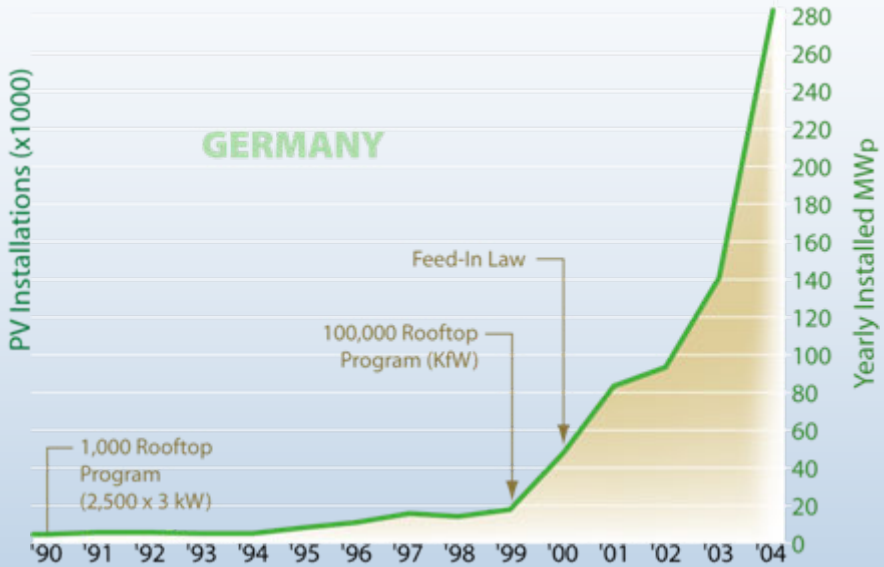
Source: NREL 2005, 2002

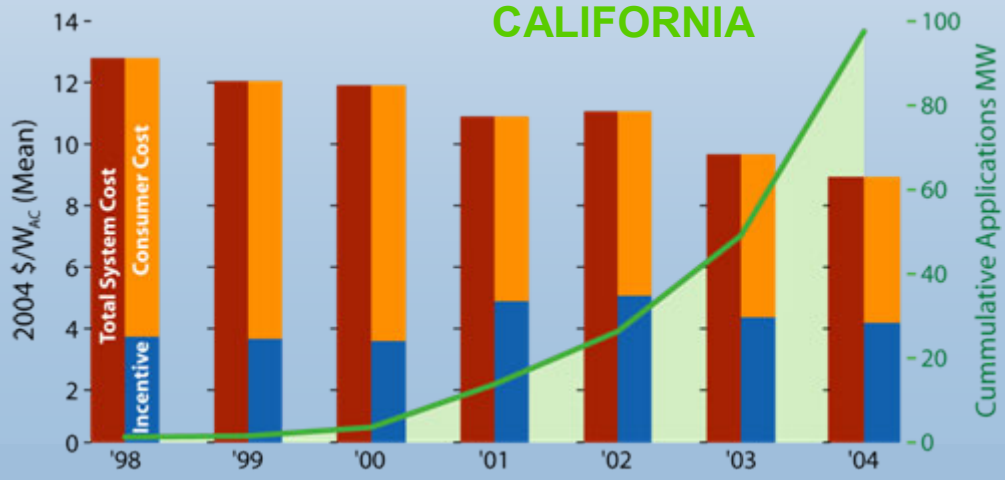
Policy

Stimulates markets

Federal, state, and local governments are the STEWARDS



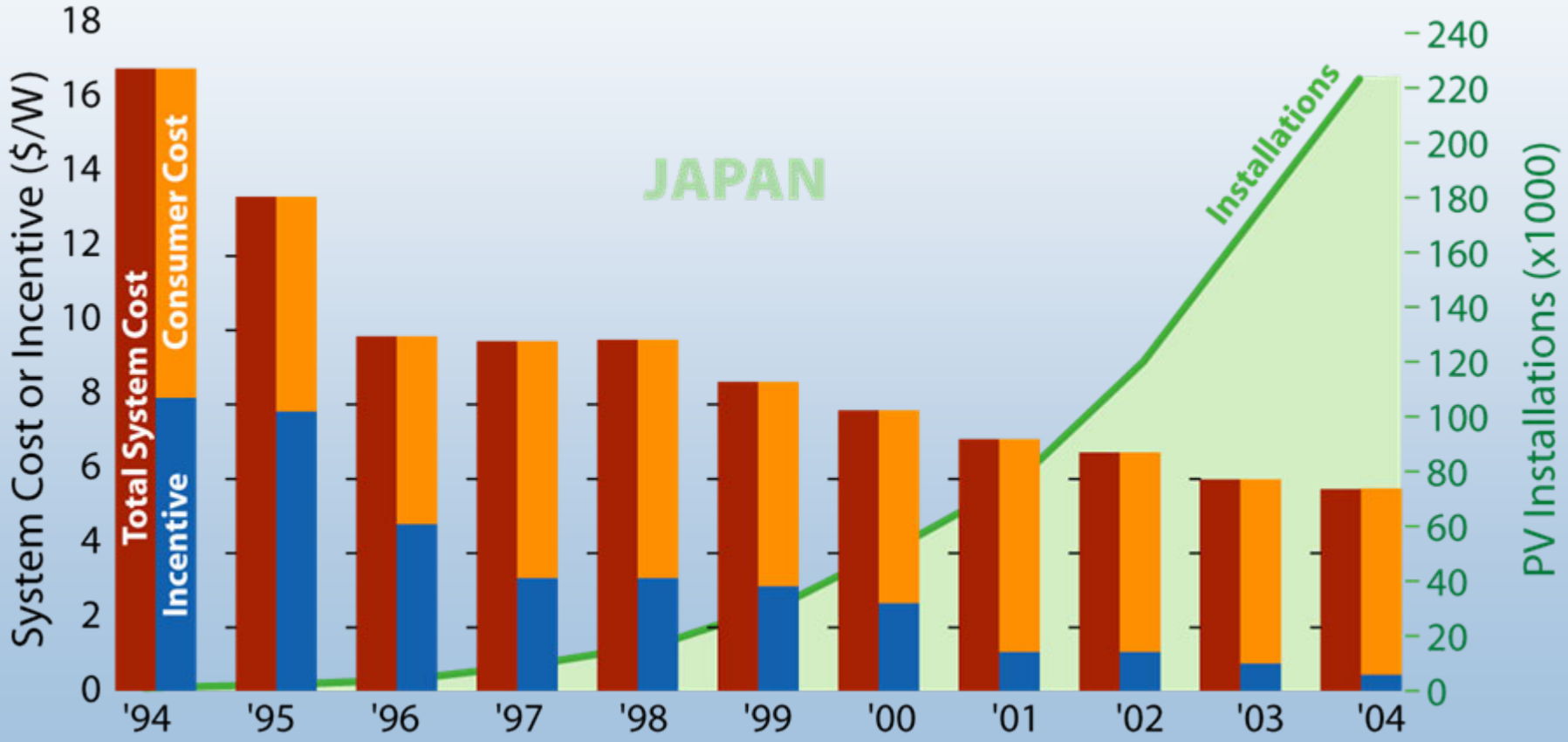


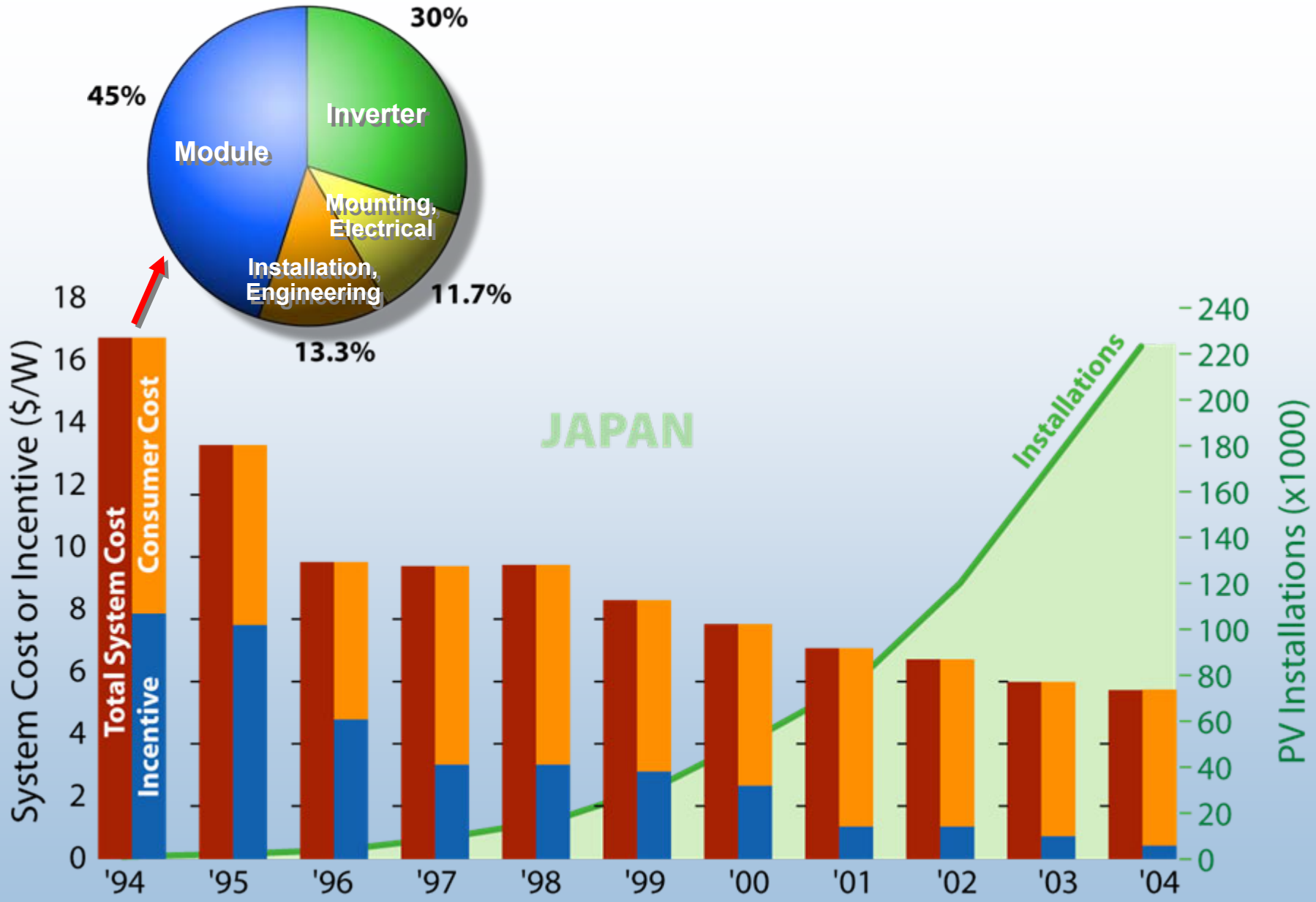


"BIG 3" Experience

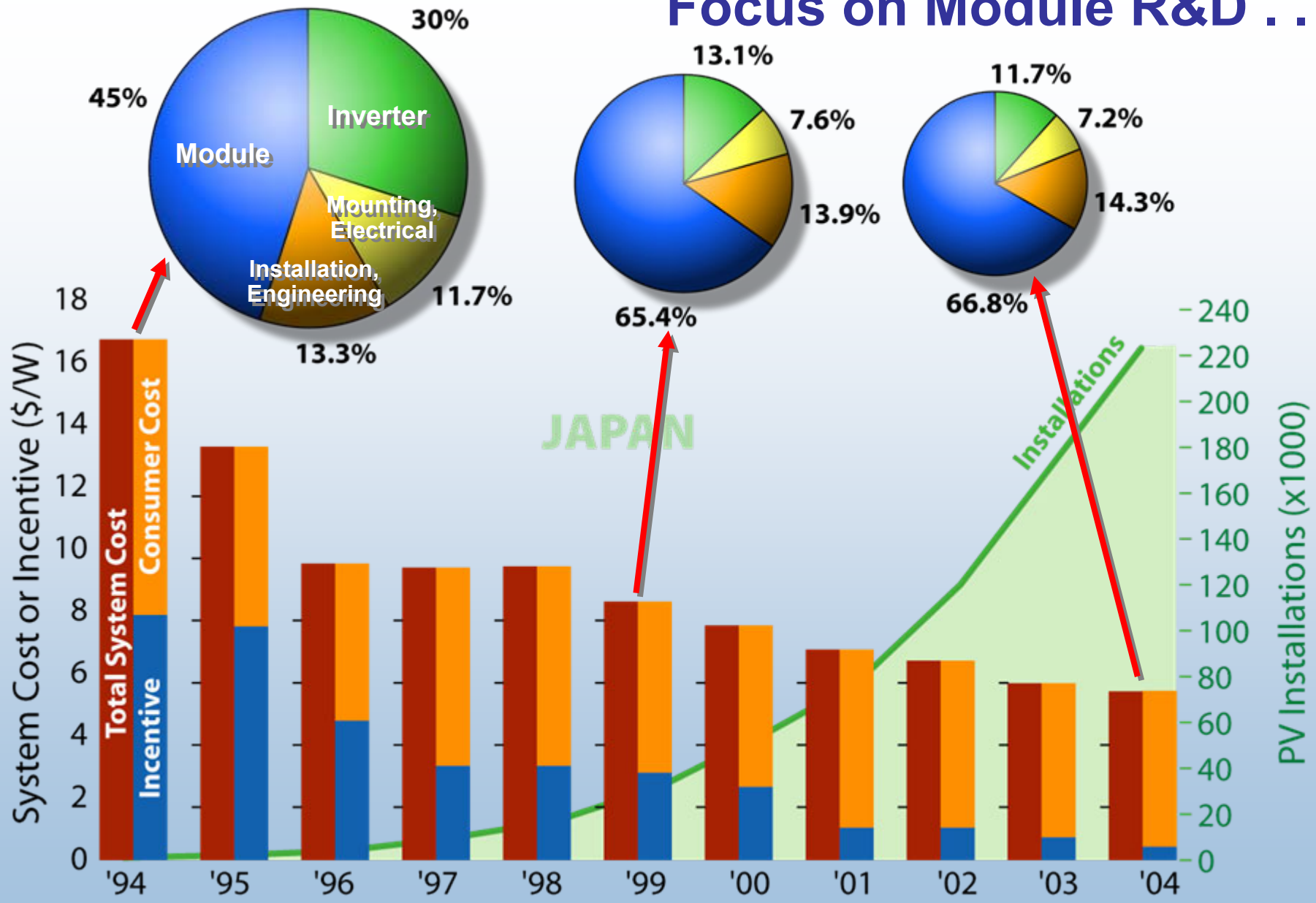
(It works . . .!)

Is Policy ALL We Need?

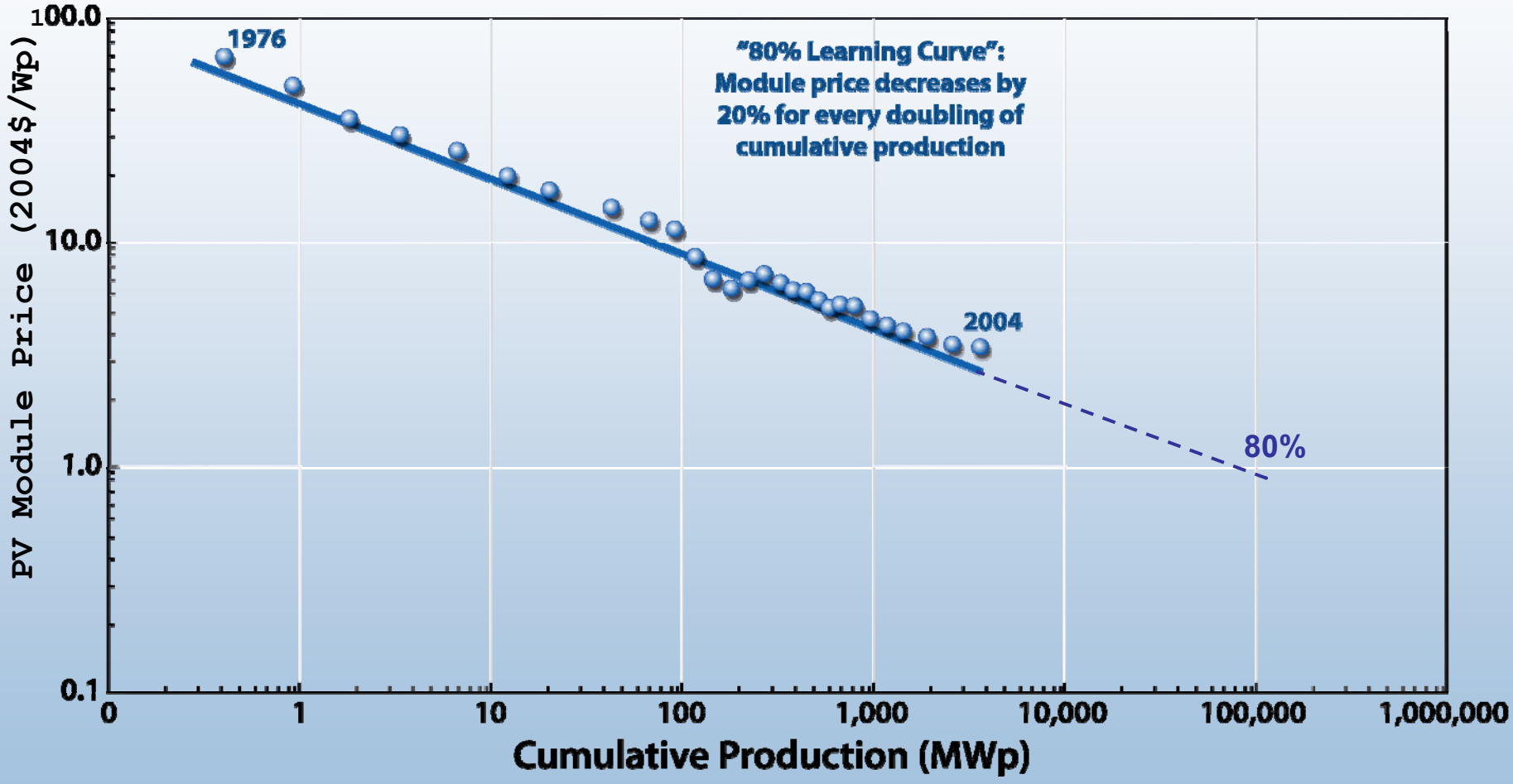



30%
45%
Inverter
Module
Mounting, Electrical
Installation, Engineering
11.7%
13.3%
JAPAN
Total System Cost
Consumer Cost
Incentive
Installations
System Cost or Incentive ($/W)
PV Installations (x1000)
0
2
4
6
8
10
12
14
16
18
0
20
40
60
80
100
120
140
160
180
200
220
240
'94
'95
'96
'97
'98
'99
'00
'01
'02
'03
'04

Focus on Module R&D . . .



PV Module Production Experience (or "Learning") Curve



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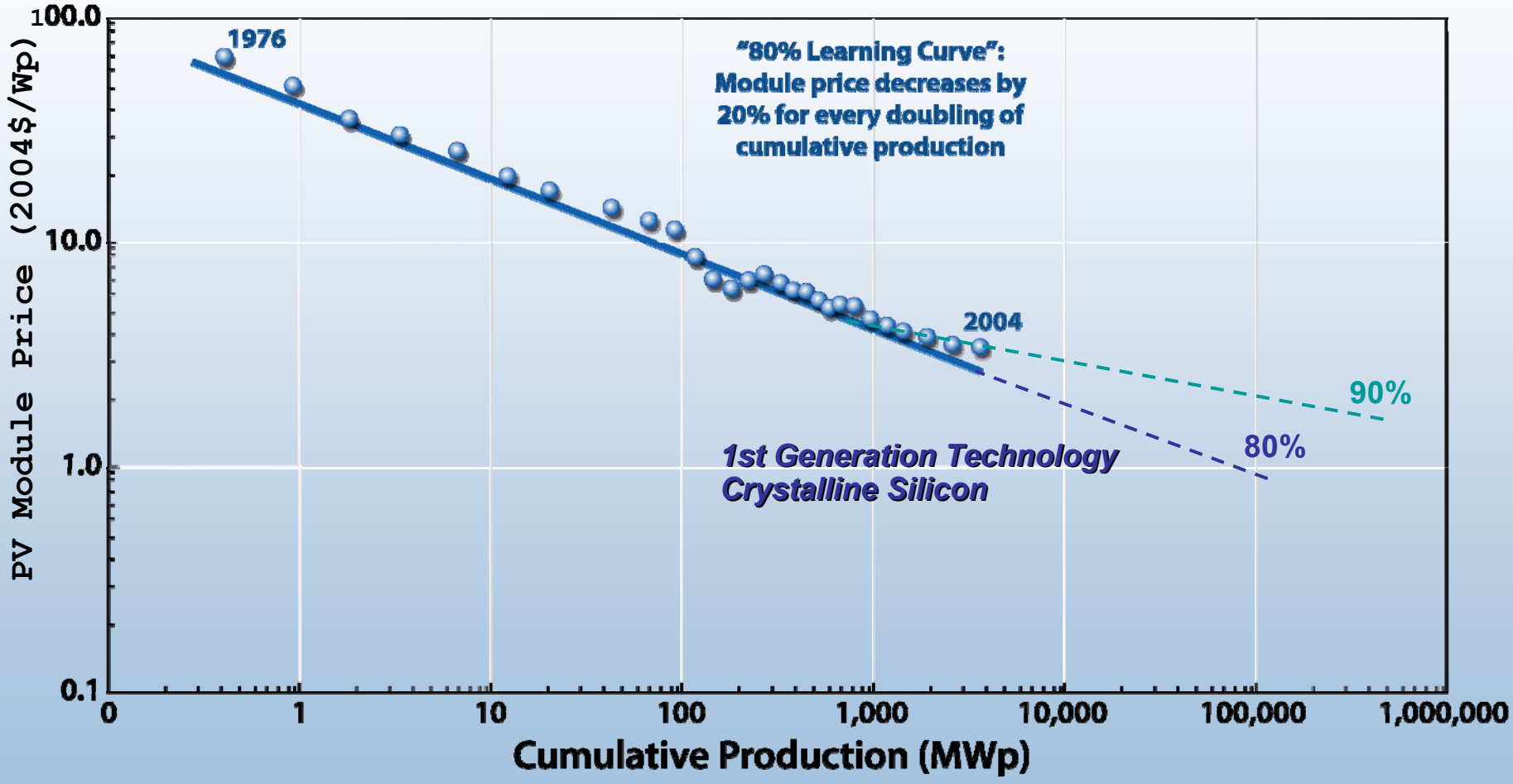
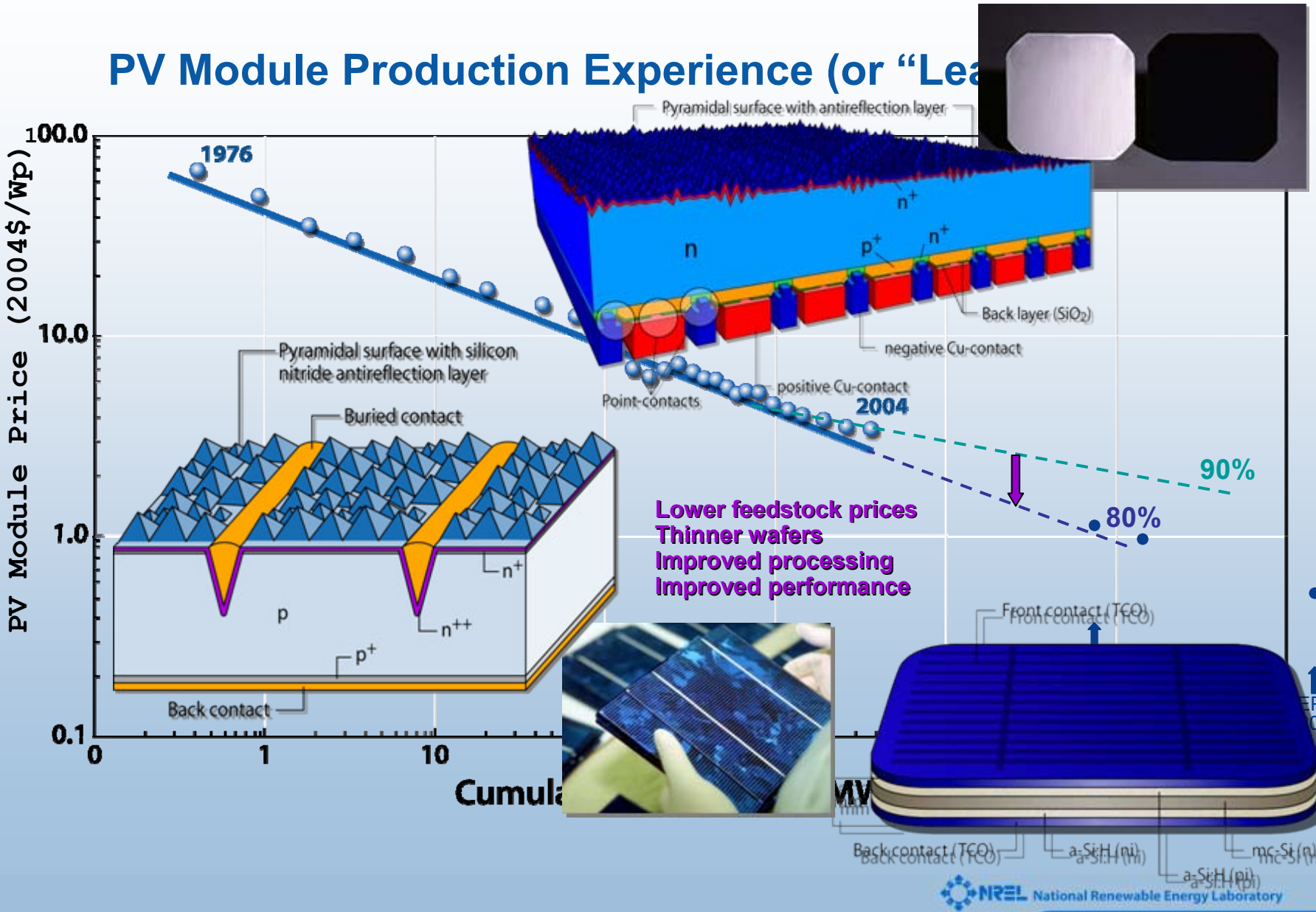


PV Module Production Experience (or "Lea



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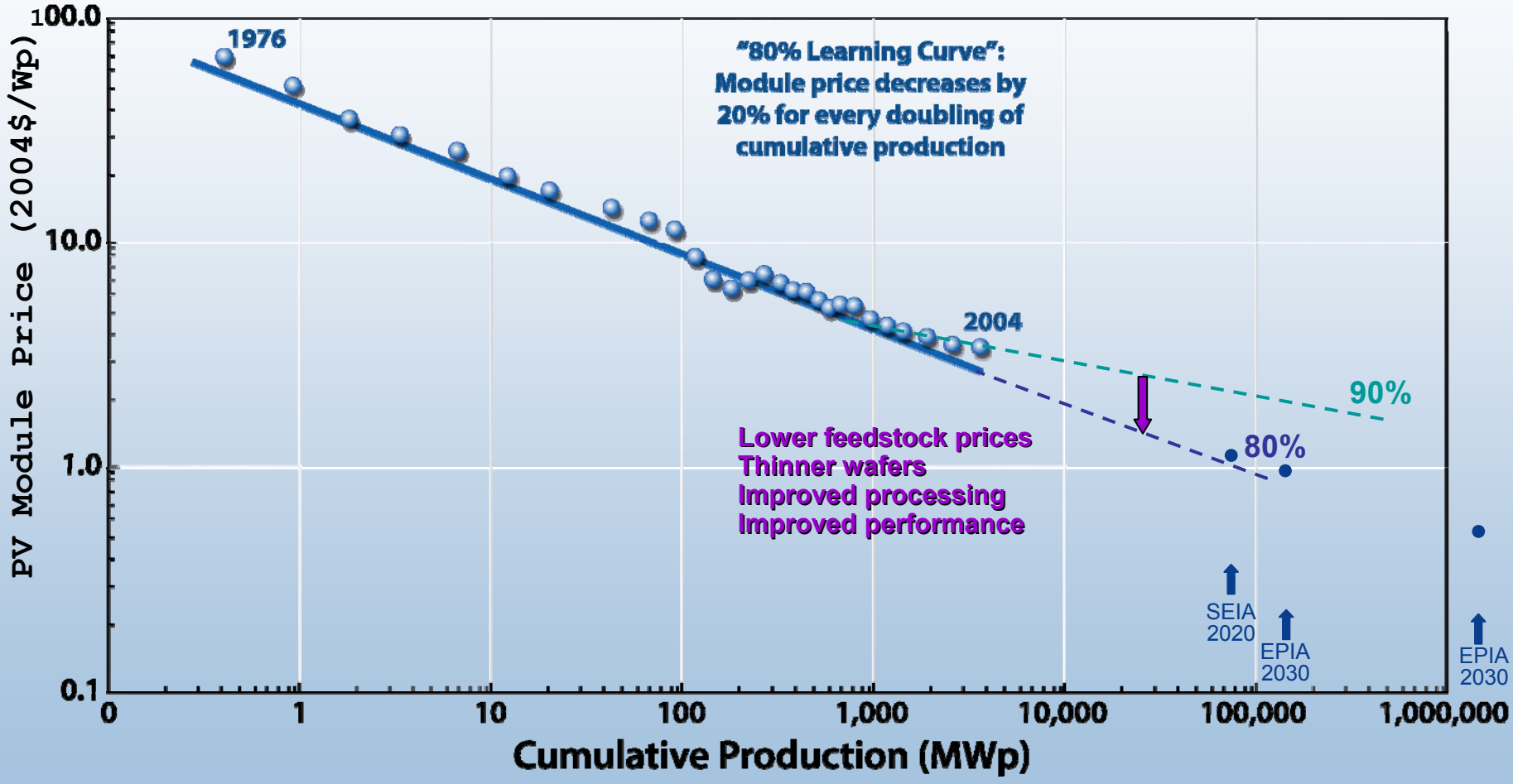
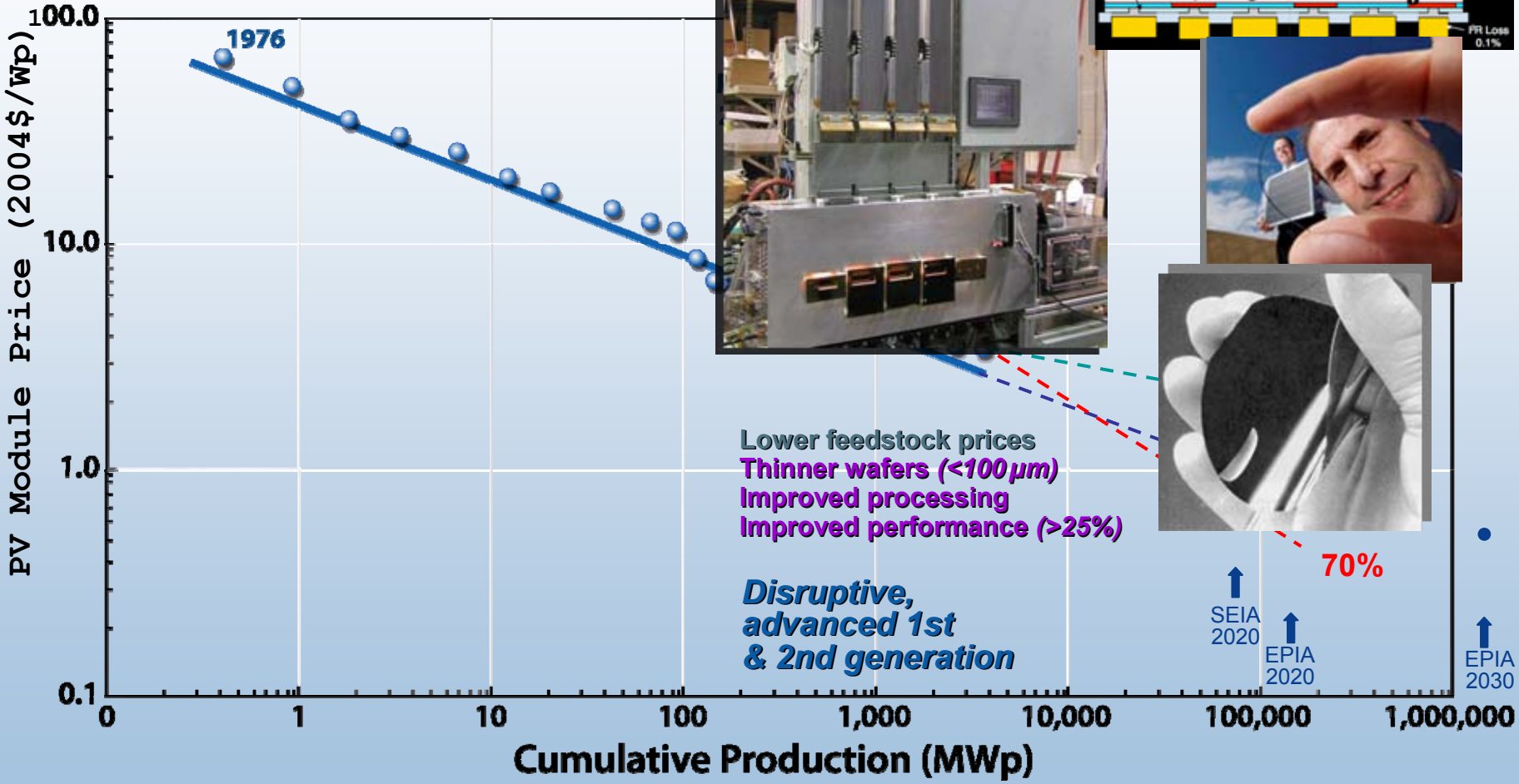


PV Module Production Experience (or "Le



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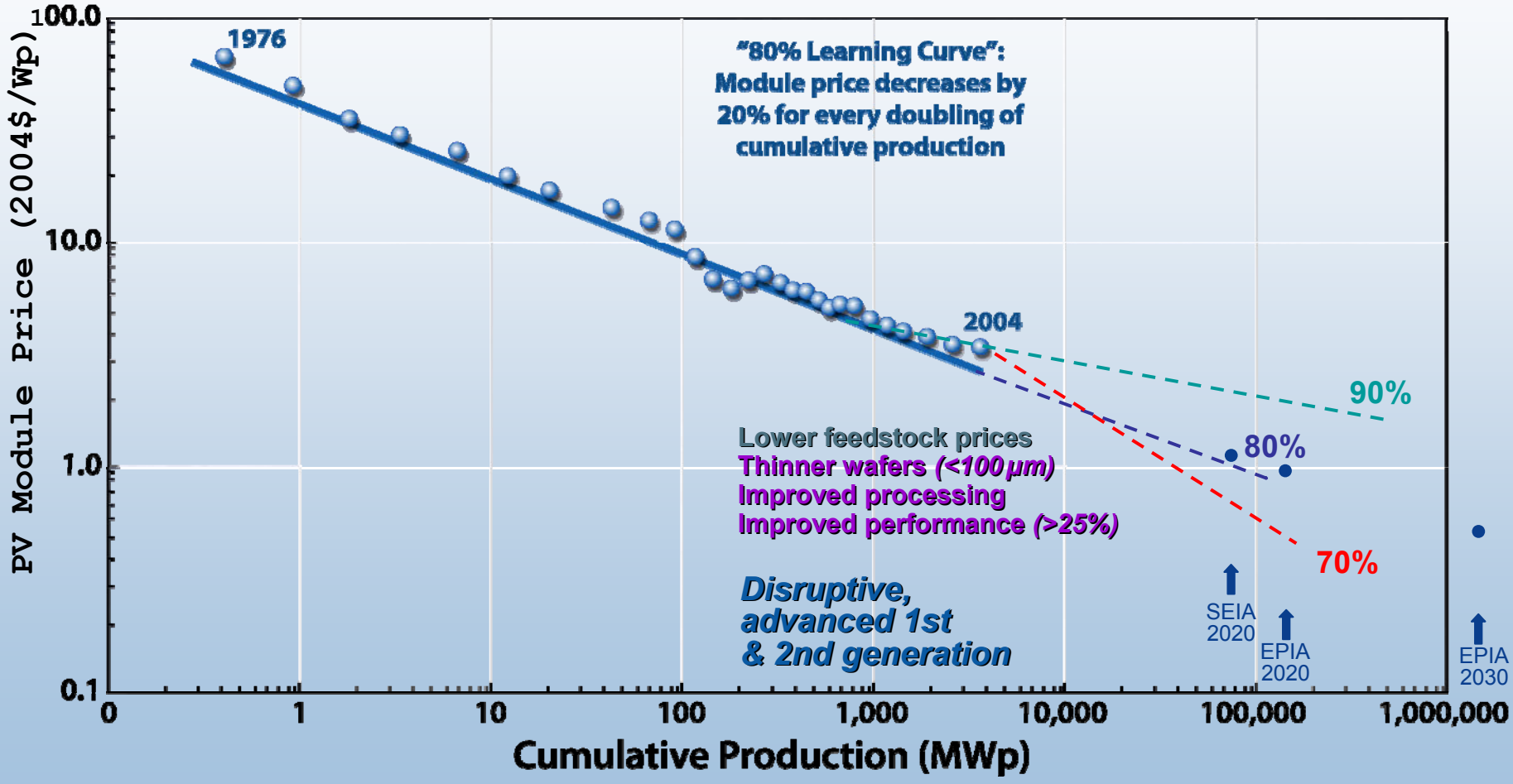

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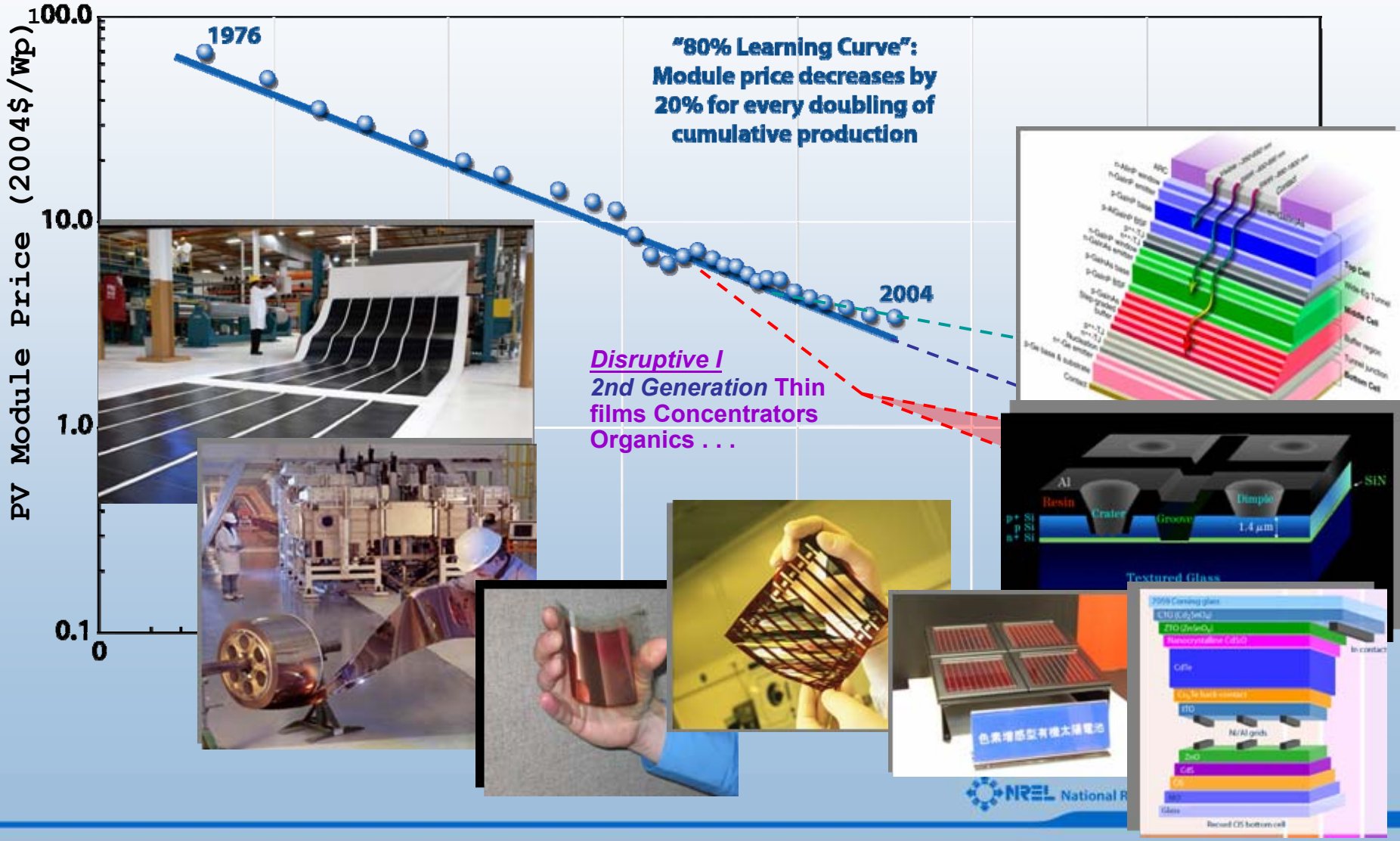

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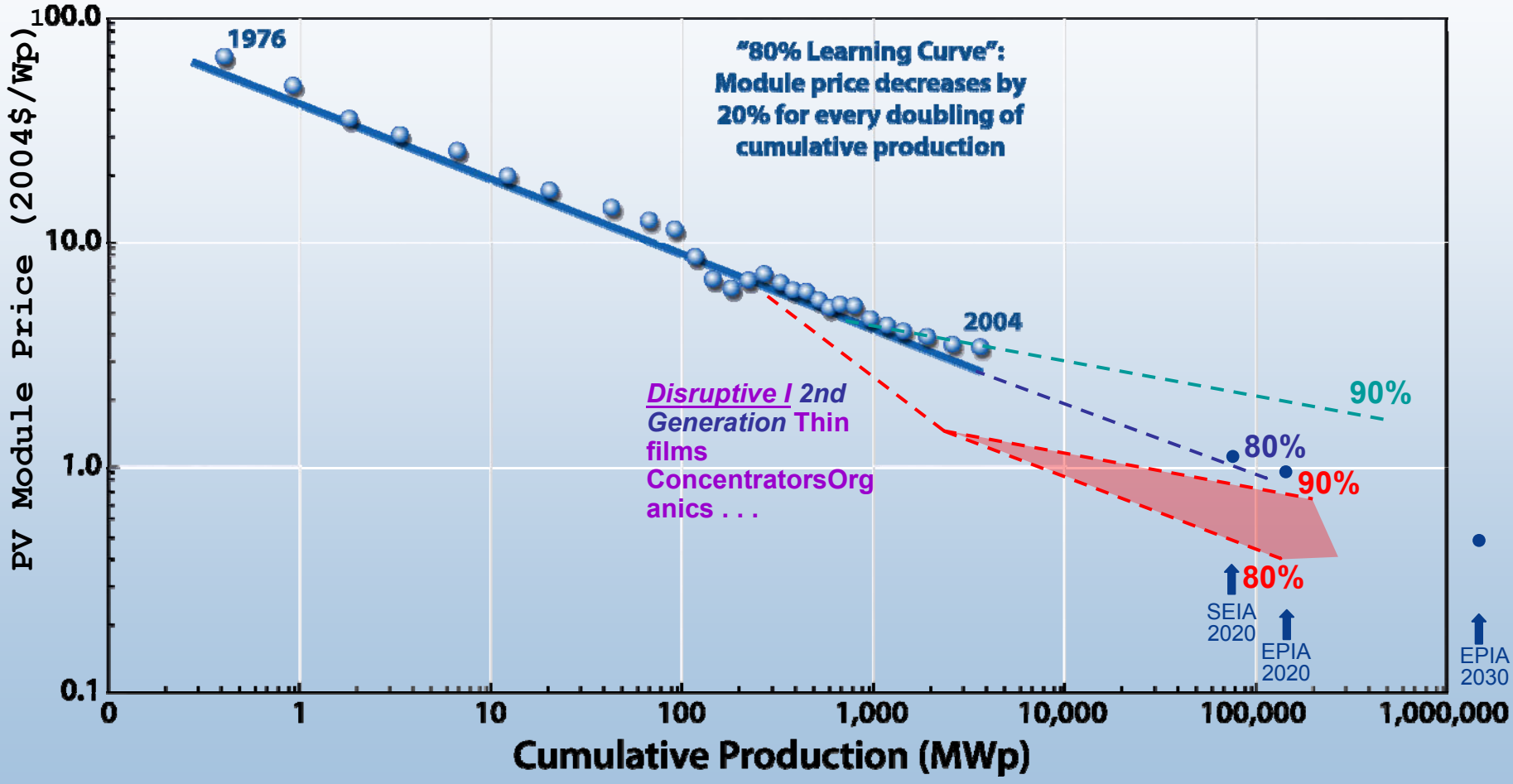
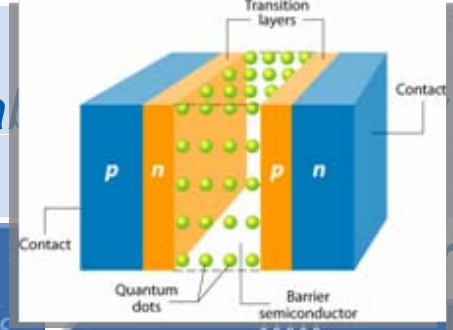


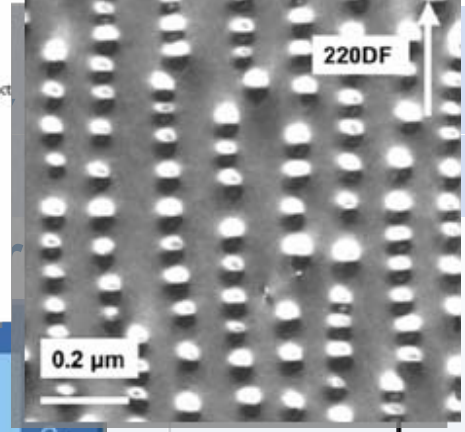
R&D

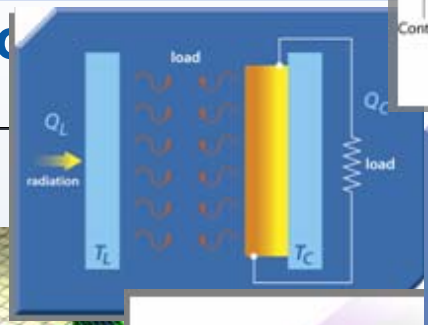
Ensures technology ownership, enal

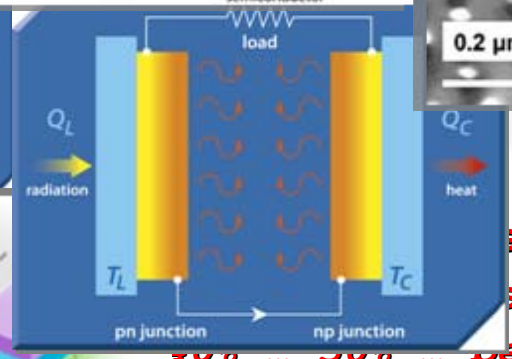
DOE is the STEWARD

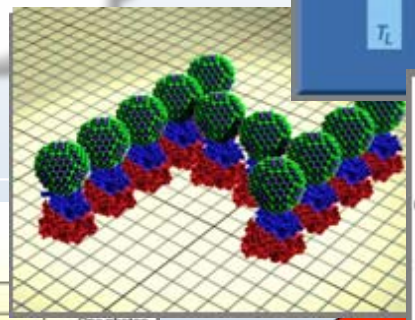
PV Module Pr

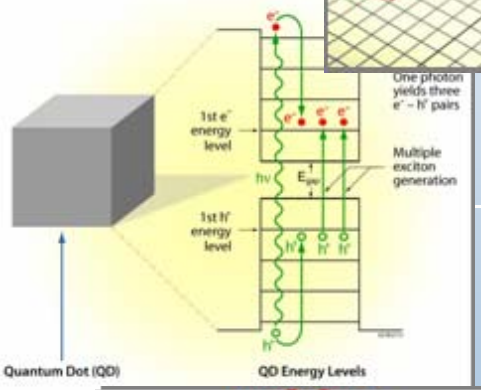


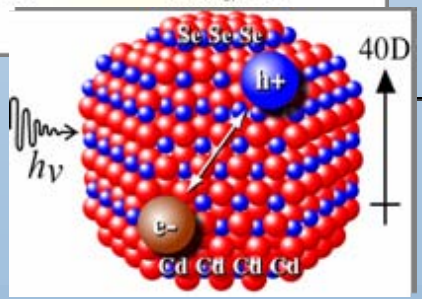












(2004$/Wp)

100

10.0

...eyond the ...ser Limit ...eyond?)

90%

80%

80%

70%

60%

Disruptive II

3rd Gen and beyond

Quantum dots

Nanotechnology

Multi-multi-junctions

Thermophotonics, voltaics

Intermediate band . . .

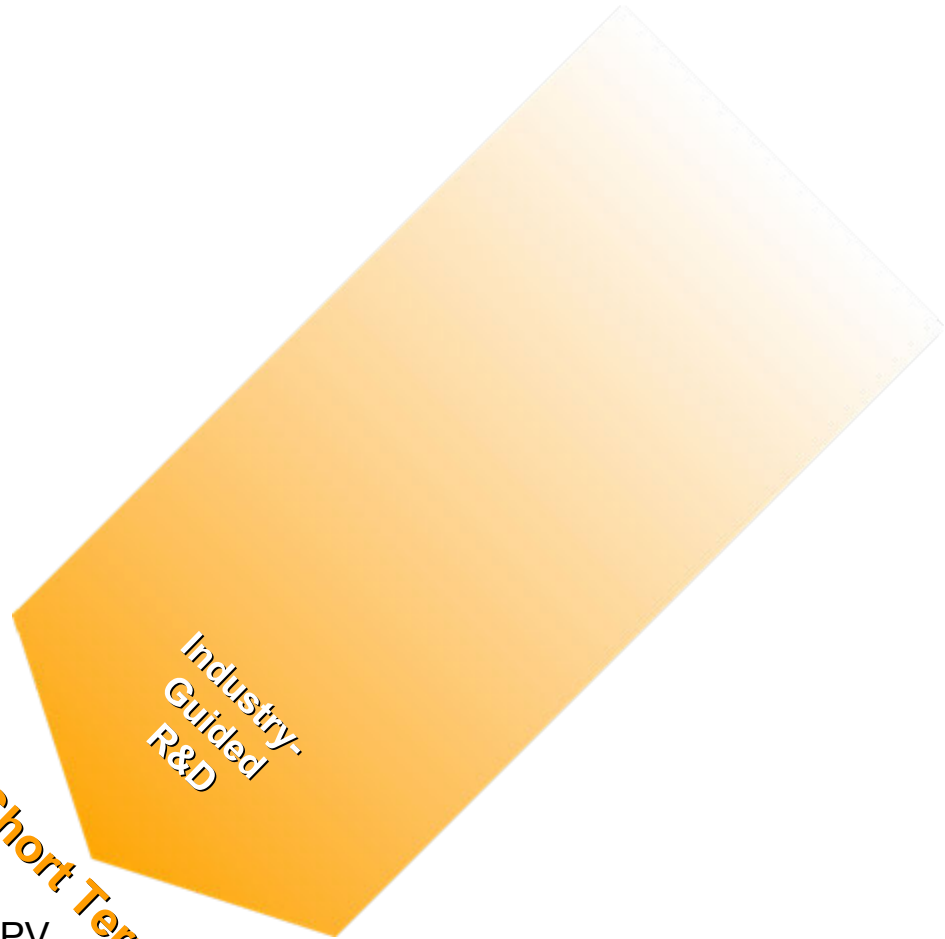
SEIA 2020

EPIA 2020

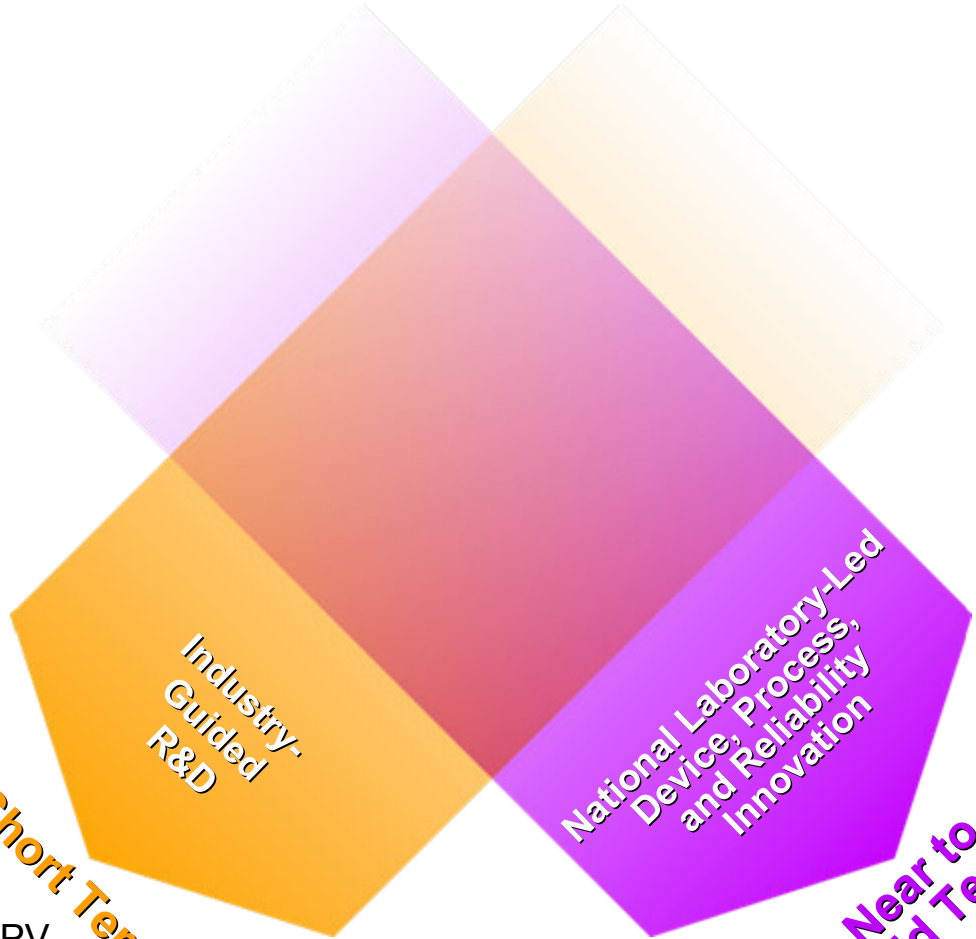
EPIA 2030

10 100 1,000 10,000 100,000 1,000,000

Cumulative Production (MWp)



1st and 2nd Generation PV
Applied Science & Engineering
Fundamental Science Support
National Laboratory and University Partners



Short Term

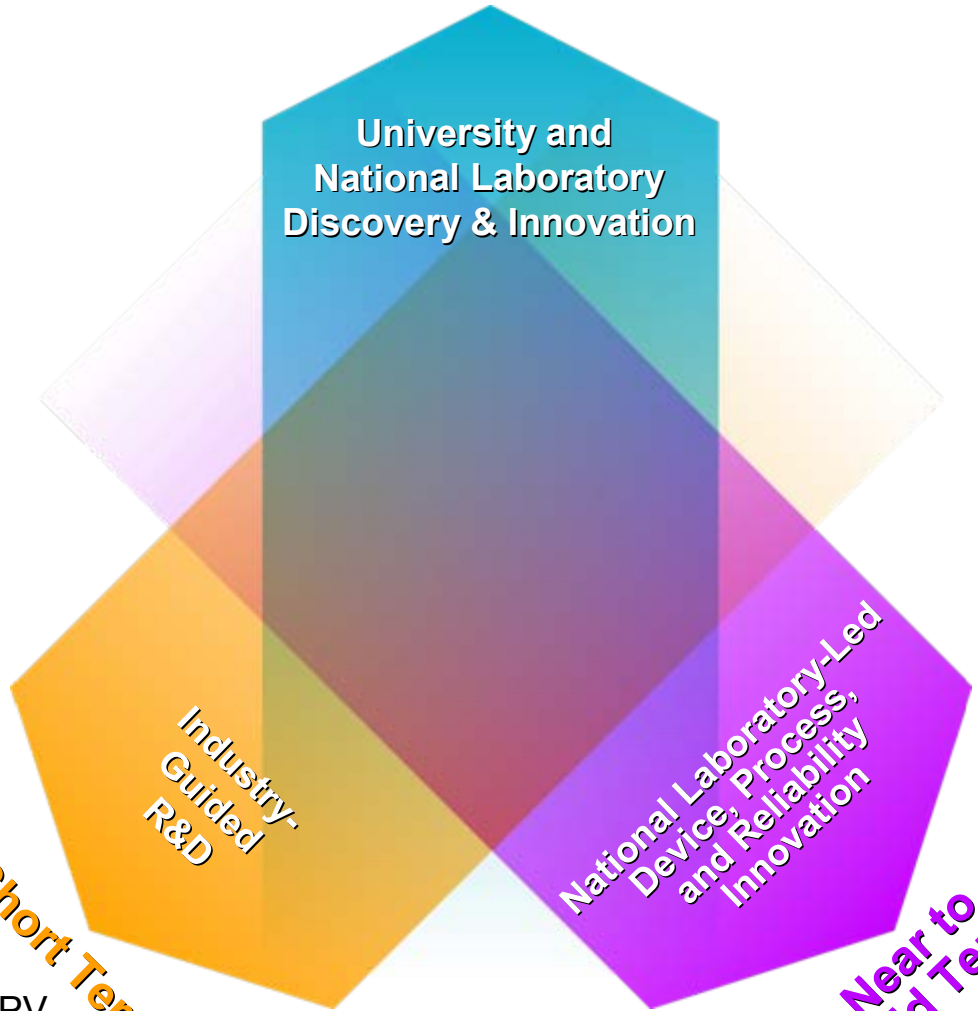
1st and 2nd Generation PV
Applied Science & Engineering
Fundamental Science Support
National Laboratory and University Partners

Near to Mid Term

2nd & Advanced 1st Generation
Applied Science & Engineering
Fundamental Science
Industry and University Partners

3rd Generation PV primarily
Fundamental Science
Advanced Applied Science

Long Term



Short Term

1st and 2nd Generation PV
Applied Science & Engineering
Fundamental Science Support
National Laboratory and University Partners

Near to
Mid Term

2nd & Advanced 1st Generation
Applied Science & Engineering
Fundamental Science
Industry and University Partners

Cornerstone:
Science & Technology Facility

Partnered and leveraged with
SC Nanoscience Centers
University Centers of Excellence
Discovery & Innovation Institutes
for success

Long Term

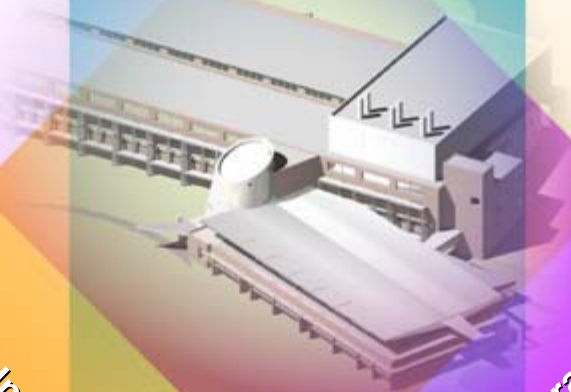
University and National Laboratory Discovery & Innovation

Closing the key gaps:
- *Time*

between concept & consumer use
from discovery to industry access
delays in re-doing previous knowledge *(data mining . . .)*

Closing the key gaps:
- *Performance*

between theory & practice
between laboratory & commercial
between discrete & integrated components



Industry-Guided R&D

National Laboratory-Led Device, Process, and Reliability Innovation

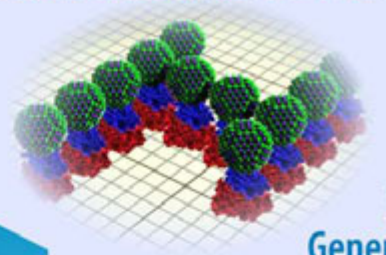
Short Term

Near to Mid Term

Bridging fundamental and applied research

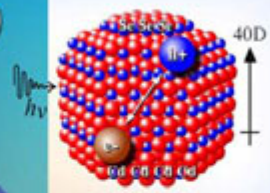
Technology Investment Pathways

Basic Research Driven



3rd Generation PV

quantum dots
nanotechnology
multi-multijunctions
thermophotonics
intermediate band
bio-inspired



Revolutionary
(10 years and beyond)

Industry Driven

Technology Driven

Accelerated Evolutionary
(3 years)

Disruptive
(3–10 years)

1st & 2nd Generation PV

lower Si feedstock prices
thinner Si wafer technology
thin films
improved processing
improved performance
advanced integration
advanced packaging

2nd Generation PV

thin films
concentrators
organics
Si wafers <100 µm
Si cells beyond 25%

…toward our destination


Ridge Vineyards PV Rooftop 65 kW, CA


WorldWater & Power, Irrigation System 267 kW, Seley Ranches, CA

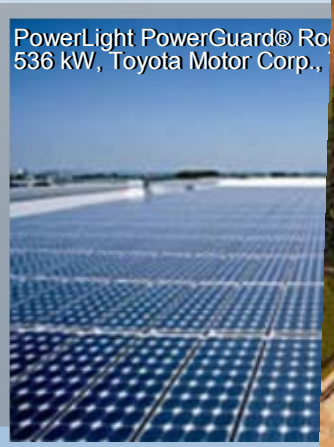

RWE Schott Stillwell Avenue Subway Station, PV Canopy Roof, 250,000 kWh/yr, Brooklyn, NY


Powerlight, Bavarian community, 6.3 MW, single-axis tracking, Mühlhausen, Germany


Shell Solar at *Semitropic Water S* 980 kW, single-axis tracking, Was


Alternity Power Treatment rld, NJ


Sun Power & Geothermal Energy Co. Solar-Wastewater Plant, 622 kW, Oroville,CA


PowerLight PowerGuard® Ro 536 kW, Toyota Motor Corp.,


Shell Solar, "Sunspot Bürstadt", rooftop system, Grid tied, 5MW, Bürstadt, Germany


The ultimate test of the human conscience may be the willingness to do something today for future generations whose words of thanks will not be heard.
-Senator Gaylord Nelson, founder of Earth Day

The U.S. Department of Energy's

National Renewable Energy Laboratory

www.nrel.gov

Golden, Colorado